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Characteristics and Heating Values of Pellets Made from Raw and Charred Rice Residues-Rubber Tree Twigs Mixture

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Abstract. In this study, the characteristics and heating values of raw pellet (RP) and charred pellet (CP) made from rice residues-rubber tree twigs mixture were compared. The carbonization process to produce the charred plant residues was conducted in a locally fabricated stainless steel kiln. Both the RP and CP were evaluated for their heating values, pellet durability, carbon and inorganic ash content. The CP had higher heating value and carbon content than the RP. However, the ash content of CP was higher. The results indicate that the pellet made from the charred rice residues-rubber tree twigs mixture could be a suitable source of renewable fuel.

1. Introduction

Malaysia produces a large amount of waste from paddy and rubber tree plantation. The rubber tree twigs from the pruning are generally left to decompose in the plantation for mulching and nutrient recycling purposes. About 3 million tons of rice straw and 0.48 million tons of rice husk are produced in Malaysia annually [1]. Open burning is a common practice to manage the paddy residues as it is the most convenient and cheapest way to get rid of them. However, open burning releases pollutants to the atmosphere and contributes to the global climate change. These crop residues should be valorized and utilized as an energy to become less dependent on fossil fuels.

Jablonsky [2] discovered that a highly significant linear correlation between the heating value of biomass and its C content. Nevertheless, content of volatile matter in rice husk is higher than in wood and coal, whereas carbon is much lower than in coal [3]. High ash content in rice husk cause barriers for energy conversion [3].

The carbon content in biochar has been reported in the range of 54 – 84% depending on the pyrolysis temperature [4]. Although biomass are decomposed during carbonization, it retains a large part of its carbon content. Biochar is produced by thermal decomposition of organic material under

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limited supply of oxygen and at relatively low temperatures (<700 °C) [5]. According to the literature, the biochar sometimes has slightly higher energy content than bio-oil [6] and can be used as a replacement of coal as well as carbon storage and also as a soil amendment. However, the low density of the biochar makes it difficult to handle and to transport. Densification of biochar into pellets could reduce material waste and improve its handling, transportation and storage.

Densification of biomass is one of the methods that can be used to increase the energy density and to overcome the handling difficulties [7]. While there are reports in the literature on the quality of pellets from other sources of biomass, little information is available on the quality of pellets generated from charred rice residues-rubber tree twigs mixture. This study was carried out to determine whether charring can improve the heating value and the physiochemical properties of pellets generated from rice residues-rubber tree twigs mixture as an energy source.

2. Experimental

2.1 Samples Collection and Preparation
The rice residues were collected from a paddy field in Perlis while the rubber tree twigs were collected from a rubber tree plantation at Sg. Chuchuh Campus, UniMAP. The samples were sun-dried for 3 days. The rubber tree twigs were chopped into 2 cm sections. The rice straws were cut into 15 cm size and kept in a gunny sack while the rice husks were ground and sieved into 1 mm and kept in a sealed container. For the raw pellet (RP) production, all the three types of plant residues were ground and sieved through a 1 mm sieve prior to pellet production. The rubber tree twigs, rice straws and rice husks were charred separately prior to the production of the charred pellet (CP).

2.2 The Charring Process
The charring process was done using a stainless steel kiln fabricated locally at the Department of Mechanical Engineering Technology, Universiti Malaysia Perlis. During the charring process, a maximum temperature of 500 °C was attained after 1 hour of ignition. The average temperature of the kiln for the entire charring process was about 340 °C. The charring process was completed in about 3 hours after which the charred product was collected. The charred materials were ground and passed through a 1 mm sieve prior to the CP production.

2.3 Pelletization
For both RP and CP pellets production, the same proportion of rice husk, rice straw and rubber tree twigs were used; 50% rice husk, 30% rice straw and 20% rubber tree twigs. The plant residues were blended using a mixer with 20 % (w/w) starch and 30 % (w/w) water added as binding agents. Afterwards, the mixture was densified using a Model PC-30 hydraulic cold press with a punch weight of 2.5 tonnes. The dimensions of the RP and CP produced were 14 mm in length and 12 mm in diameter.

2.4 Pellet durability
Pellet durability was determined by mass loss upon vibration. The pellet durability was calculated using the following equation:

$$Pd = 100 - ((mi - mf)/mi) \times 100\%$$

where, Pd is tablet durability (%), mi is initial mass of samples (g), and mf is final mass of the samples (g).

2.5 Inorganic Ash
Inorganic ash contents of the pellets were determined by calculation from the inorganic ash remaining in pellets after the samples were heated in a DAIHAN WiseTherm digital muffle furnace at 600°C for 2 hours. About 2 g of the pellets were weighed on an analytical digital balance (0.0001 Resolution) and then placed in a crucible at 600 °C for 2 hours. The crucible was removed from the muffle furnace

and cooled in a desiccator. Then, the crucible was weighed on a precision digital balance and the inorganic ash content was calculated based on the following equation:

$$\text{Inorganic ash, Ia (\%)} = \frac{\textit{weight of inorganic ash remaining}}{\textit{initial weight of pellet}} \times 100\%$$

2.6 Carbon Content
Total carbon (TC) of the RP and CP were determined by a LECO CNS elemental analyzer.

2.7 Heating Value
The caloric value of the RP and CP were measured using IKA model C200 Bomb Calorimeter. About 0.005 g RP or CP sample was introduced into the calorimeter and burnt under oxygen about 5 minutes and the reading were recorded.

3. Results and Discussions

3.1. Pellet durability
According to Adapa [8], durability is high when the computed value is above 80%, medium when the value is between 70% and 80%, and low when the value is below 70%. The raw biomass (RP) shows a significantly higher (96.18%) than the charred biomass (CP) (76.56%). A lower durability of CP could be attributed to destruction of some hydroxyl groups of the biomass materials during the carbonization [9] and reduce binding sites for hydrogen bonding to occur between particles [10]. High durability of RP (96.18%) met the lowest limit standard for both industrial and domestic uses [11].

3.2 Total carbon content
The TC of CP (46.13%) was significantly higher than the RP (39.10%). This difference could be attributed to the carbonization process which condensed the carbon of the rice residues-rubber tree twigs mixture, thereby increasing the carbon content after carbonization. The energy content in C=C bonds is high therefore more energy per unit mass will be observed in pellets with higher TC content [12].

3.3 Inorganic ash content and heating value
As shown in Table 1, the inorganic ash of RP was significantly lower (8.54%) than that of CP (30.25%). The inorganic ash of RP pellet was consistent with the ash content of wood-straw residue reported in the literature [13], while the ash content of CP pellet (30.25%) fell within the range of ash content in coal compiled by Vassilev [13]. Similar observation for high ash content of biomass after thermal treatment have been revealed in the literature [13]. This is most likely due to the pellets consist of paddy residues are rich in silica (Si) [14] and subsequently formation and condensation of aromatic Si-C occur during carbonization process [15]. The CP pellet with higher inorganic ash content seems to less desirable as fuel because it will have lower bioenergy conversion efficiency.

Table 1. Inorganic ash content and heating values of pellets made from raw and charred rice residues-rubber tree twigs mixture

Types of pellet	Inorganic ash content (%)	Heating value (MJ/kg)
Raw pellet (RP)	$8.54^{*b} \pm 2.03$	$15.00^{b} \pm 0.04$
Charred pellet (CP)	$30.25^{a} \pm 0.35$	$15.32^{a} \pm 0.03$

The heating value is the amount of energy that a mass unit releases when upon combustion. The heating values of the RP and CP pellets were greater than the heating value of rice husk (12.87 MJ/kg) and rice straw (14.87 MJ/kg) reported by Biswas [16]. High heating value of RP and CP pellets suggests addition of rubber twigs together with densification increased the heating value as compared to the rice husk or rice straw separately. The higher heating value of the CP can be attributed to its higher TC as C-C bond has higher energy content if compared to O-H, C-H or C-O bonds [12]. Similar observation was obtained by Biswas [16] who found the agricultural residues with high C content released more energy per unit mass.

4. Conclusions

The effects of carbonization on pellet durability, carbon content, inorganic ash content and heating value were statistically significant. After being carbonized, the carbon content and heating value of the rice residues-rubber tree twigs pellets were improved. However, the carbonization process increased the ash content and reduced durability of the pellets. The carbonization process parameters should be varied and investigated in further improving the quality of agricultural residues derived pellets.

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